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INTRODUCTION

The history of range reseeding research by the Forest Service at Ephraim, Utah, has been long and fruitful. Observational plantings were made as early as 1907. With the establishment of the Great Basin Research Center in 1912 range reseeding research was started on an organized, although limited, basis. This research was continued until 1935 when sufficient money for an expanded reseeding research program became available. Except for a brief period during World War II, this expanded program continued until December, 1953, when most of the reseeding research was transferred from the Forest Service to the Agricultural Research Service.

Because of the recent reorganization of the range reseeding research program, it is felt that now would be a desirable time to reanalyze the range reseeding problems of this area. A summary of past results of range reseeding research appears in the 1953 Annual Report of the Intermountain Forest and Range Experiment Station; no attempt to summarize past research will be made in this report.

The general area covered by this problem analysis report is essentially the same as the area covered by the Great Basin Research Center. This area covers the fifteen southern counties of Utah and is deliniated on the north by the north boundaries of Juab, Sanpete, Carbon, and Grand Counties. These fifteen counties occupy about 60 percent of the surface area of Utah.

Although this report is confined to southern Utah, it is not implied that the problems of southern Utah do not extend into similar areas in adjacent states, or conversely.

HISTORY OF THE AREA

In the latter part of the Eighteenth Century, Father Escalante explored part of what is now Southern Utah, but no colonization resulted from his explorations. The early trappers led by Jedediah Smith came into northern Utah in search of fur; they were not interested in the agricultural possibilities of the area. The first pioneer settlers in the state were the Mormon pioneers, who came in 1847. Immigrants came in large numbers during the years immediately following 1847. Under the aggressive leadership of Brigham Young, the Mormon settlers by 1860 had established small communities at almost every location in the state where water and arable land were available.

The general pattern of settlement in Utah differs greatly from that of most of the rest of the western United States. Under the supervision of the Mormon Church, the settlers built planned towns, and each family was assigned small farm plots near these towns. These individual farms were no larger than were required to support one family. Large Spanish-type farms and ranches were unknown. The unallocated non-farm land around the Utah villages was used as common use range without regulation.

General view of central part of Sanpete Valley and the City of Ephraim. Note the small size of the farm lots and the lack of farm houses outside of the city proper. This is a typical small community in south central Utah.

The small-farm type of agriculture continues even today with one notable exception. In the 1880's, large migrant bands of sheep came into the area. Many of these bands were owned by residents of Utah, but many other bands came in from neighboring states. By 1890, the numbers of sheep had far exceeded the sustained carrying capacity of the range land, and the ranges and watersheds were soon seriously damaged. The establishment of the National Forests in 1906 brought this situation under partial control, but the damage had already been done. Some of the high mountain areas were so severely damaged that even after 40 years of complete protection in small enclosures, little improvement can be seen in the depleted native vegetation. The sagebrush areas adjacent to the villages and towns have suffered severely, not only from the migrant herds, but also from the small bands of livestock from the villages. A number of the large herds are still being operated today.

The depletion of the range resource has intensified the problems of Utah's agriculture. The size of the individual farm 100 years ago was too small to allow the farmer any more than a bare living, and even then, he had to depend upon the adjacent range areas. There has been very little concentration of land into larger farms; the average acreage per farm is much the same now as it was in 1855. The mechanization of farming has intensified the problem of these small holdings. The small holdings coupled with a deficiency of irrigation water and a depleted

range resource have put the Utah farmer in a poor economic position. In 1951, the average income per farm in Utah was next to the bottom when compared to the other eight mountain states.

IMPORTANCE OF THE RANGE RESOURCE

In 1947, the value of the agricultural produce in Utah was $169,100,000. In the same year, the value of products from mining was $207,000,000, and from manufacturing was $128,300,000. Thus, the value of products from agriculture amounts to 33 percent of the total value of products produced in the state.

Of the total agricultural income, 70 percent comes from livestock and livestock products. Fifty-five percent of the income from livestock and livestock products comes from beef cattle and sheep. Eighty percent of the income from beef cattle and sheep is directly attributable to the range or other dry land. Thus, 30 percent of the total agricultural income comes directly from the range; this amounts to about $50,000,000 annually.

With the exception of the high mountain area, much of Utah's range land is the least desirable land in the state. In addition, most of the ranges are producing substantially less than their potential. When one considers that about 88 percent of the state is classed as rangeland, it will be seen that the ranges are contributing very little per acre toward the state's economy.

It is felt that much of the range area will require reseeding if it is to be put in a highly productive condition within a reasonable period of time. Reseeding will be particularly valuable on the higher potential areas such as the sub-alpine and sagebrush types.

LAND USE

In 1949, the major land uses in Utah were as follows:

	Percent
Cropland, including irrigated pasture land	3.3
Range land open for grazing	87.8
Special use areas	6.1
Barren land	1.6
Not accounted for	1.2
	100.00

The known arable lands within the state amount to about 6 percent of the total land area. About 1/2 to 2/3 of the arable land not now cropped in the Great Basin Province is so far removed from any major sources of irrigation water that putting this land into crop production is not possible in the foreseeable future.

Most of the better quality cropland is located in Northern Utah. In the fifteen southern counties of Utah, only 2.05 percent of the land area is presently cropped. With little chance of increasing the amount of cropland in Southern Utah, any improvement in the agricultural economy of the area will of necessity come from the rangeland.

Actually, much of the irrigated land in Utah is now inadequately

watered. The principal use of the water to be diverted into the area from the proposed Upper Colorado River Development would be to supplement the present inadequate supplies. Some additional land would be placed under irrigation. Even with adequate water, much of the irrigated cropland in Southern Utah could not be used for anything but pasture, hay, and small grains because of the unfavorable climate; much of the cropland in Southern Utah is located in the higher valleys and the frost-free growing season is relatively short.

WATERSHEDS

Well over half of Utah's total agricultural income comes from irrigated cropland. Most of the water for this irrigated cropland comes from about 20 percent of the land area classed as water yielding land at elevations of 7,000 to 13,000 feet. Actually, most of the water comes from a relatively small segment of the water-yielding land at elevations above 9,000 feet. Most of the water-yielding land is also rangeland.

At the present time, there is little indication that herbaceous vegetation has any noticeable effect on the total amount or seasonal distribution of stream flow. The Forest Service is presently evaluating some of the seeded species in terms of the water deficit they create during the growing season; this deficit must be made up before stream flow can begin. However, one phase

of watershed management where reseeding can have a vital influence is that of flood prevention from high intensity summer storms. These high intensity summer storms make up less than 5 percent of the average annual precipitation, but they are capable of doing millions of dollars worth of damage. Even when they do not cause floods, these summer storms usually increase the sediment yield from the watersheds and do much damage by causing siltation in ditches and on fields. Sediment discharge and floods are inversely related to the vegetative cover. Where reseeding can increase the permanent vegetative cover, it can reduce the incidence of floods and reduce the amount of sediment in the streamflow.

One possibility of reseeding increasing water yield is on watersheds covered by woody vegetation. It is thought that many of the shrubs and trees are able to extract water from the soil to greater depths than can herbaceous vegetation, the amount of water released to streamflow might be increased. This whole field needs further study.

PHYSIOGRAPHY OF THE AREA

The elevations of the range areas in Southern Utah run from a low of about 2,500 feet in Washington County up to 13,000 feet on the top of Mt. Peal in the LaSal Mountains. The average elevation of Southern Utah is around 6,000 feet. However, most of the valleys have an average elevation of 4,000 to 5,000 feet,

while most of the mountains are less than 11,000 feet high.

Two physiographic provinces are represented in Southern Utah. The western eastern half of the area is in the Great Basin Province which is characterized by large block-fault mountains of north-south orientation. The mountains are steep and mostly without foothills. The valleys between the mountains are relatively level and frequently contain a lake which may be dry most of the year; these lakes are usually salty. Except for the extreme southern end of the area, most of the streams in this province flow into closed interior lakes much as Great Salt Lake or Sevier Lake. Most of the geological formations of the province are of sedimentary origin, although igneous and metamorphic rocks are common.

The Colorado Plateau Physiographic Province occupies the eastern half of Southern Utah. The geological formations of this province consist of rocks primarily of sedimentary origin. It is typified by high plateaus and canyon lands. Many of the plateaus are broken by faults. All are disected by canyons with steep faces; Indian cliff dwellings are common in these steep faces in the south-east corner of the state. Except for very localized areas, all drainage in this province is into the Colorado River or its major tributaries.

CLIMATE OF THE AREA

The climate of this area is quite variable depending on the location, but, in general, the climatic zones follow closely the variations in physiography. The climatic factor having the greatest effect on range reseeding is effective precipitation. Although temperatures are such as to limit crop production in many parts of the area, temperature as a limiting climatic factor is of relatively small importance when compared to soil moisture. In general, if soil moisture is adequate, some valuable forage plant can be found that will do well under the accompanying temperatures.

Annually precipitation is closely tied to elevation in Southern Utah. The valley floors with elevations of 4,000 to 6,000 feet seldom have an average annual precipitation exceeding 12 inches; in the western part of the state ("the West Desert"), precipitation is generally less than 8 inches, and has been as low as 2.5 inches in dry years. At the lower elevations, the seasonal distribution of precipitation is usually fairly good, but the springs and summers are frequently dry. One characteristic of the precipitation is an extreme variation in total annual and the seasonal distribution of the precipitation between any two years. This variability constitutes a major hazard to reseeding.

Total annual precipitation increases with elevation; the relationship of altitude and precipitation is not a linear function but approaches it. The high plateaus and mountains have an average

elevation of about 10,000 feet with an average annual precipitation in excess of 35 inches. However, 75 percent of the annual precipitation at this elevation comes in the form of snow. The melting snow will usually completely recharge the soil mantle, but much of snow water is lost to streamflow either by overland flow or through deep seepage. In general, soil moisture is adequate during most of the growing season at this elevation.

The average annual precipitation for the lands at elevations between the two extremes mentioned above is variable but lies somewhere in between. The average annual precipitation for all weather stations in the state is about 13 inches. Periodic drouths are a characteristic of the area.

The average annual temperature for all stations in the state is 48 degrees. At the lower elevations, maxima in excess of 100 degrees are common but those in excess of 110 degrees are rare. Winter minima for all parts of the area, except parts of Washington county, are frequently below -30 degrees, but a -40 degrees minimum is rare. The daily spread in temperature between the minimum and maximum is usually great; in the desert area, a spread of 40 degrees is usual and a spread of 60 degrees is not uncommon. This spread is less pronounced at the higher elevations.

The frost-free period between killing frosts (28 degrees or below) varies from well under 30 days in the mountains to 250 days in Washington county. The average frost-free period for most of the cropland in Southern Utah is not much over 100 days.

SOILS OF THE AREA

The soils of Southern Utah are as diverse as its climate, vegetation, and topography. Most of the rangeland soils are young and relatively poorly developed. Almost all the soils have a well developed carbonate layer, and in some soils, this layer is tightly cemented and impervious. In addition, most of the soils developed in the low rainfall sections of the area are at least slightly saline and alkaline; some are very saline and strongly alkaline, particularly near old dry lakes. Most soils, when judged by normal standards, show a pronounced nitrogen deficiency. However, when considered in the light of the amount of available moisture, this deficiency may not be as great as it appears; this field needs more investigation. Many soils are on moderate to steep slopes and almost none are entirely free from stones. Although many of the better soils in the valleys are located on alluvial fans, most are underlayed by large river deposited stones. The abundance of stones in many places prevents cultivation of soils that might otherwise be useable for farming.

The soils in Southern Utah fall into five of the great soil groups; about 75 percent of the soils fall into the Gray Desert, and Lithosols, and Shallow Soils groups. Most of the desert areas are classified as belonging to the Gray Desert group; the desert soils in the western part of Utah are in the Portneuf-Sagemoor series while those in the eastern part are in the Navajo-

Chipeta series. The other major soil group in the area is the Lithosols and Shallow Soils (arid - subhumid). Most of these soils are in the McCammon-Deschutes series, but the Underwood-Babb series is also represented. Quite a large acreage in the Colorado Plateau Province is in the Lithosol group and is classed as "rough stony land not forested". A small acreage in the south central part of the area has been put in the Gray Brown Podzolic group, Helmer-Santa-Benevah series. Also, a small acreage of the Chestnut group, Hyrum-Bingham-Avon series, is found near the LaSal Mountains. Limited and highly localized acreages of Bog, Solonchak, and Solonetz soils are common in the valley bottoms. Several other groups are probably to be found in the area, but detailed soil maps are not available for most of the range area; except for very broad classification work, most of the soils work in the state has been confined to the arable lands.

RANGE LAND VEGETATION TYPES

The only vegetation map available for Southern Utah is based on the Forest Service range survey types. These types are based more on the aspect of the vegetal cover than on strict ecological classifications. However, this range survey type map does give a generalized picture of the major forms of vegetation in this area. Following is a summary of the percentage of the range area in the 15 southern counties in Utah falling into the various range survey types:

Type	Percentage of range land area
Pinyon-Juniper	37.66
Desert	36.54
Sagebrush	13.79
Broadleaf Trees	3.46
Grassland	3.43
Browse	2.97
Conifers	2.15
	100.00

The broadness of the range survey classification introduces some ambiguities. The pinyon-juniper type includes a large acreage of the sagebrush-grass type with a sparse overstory of juniper trees; the soil and vegetal conditions of such an area would be completely different from the dense pinyon-juniper lands usually found on rolling or steep rocky land. Similarly, the desert type includes the salt desert shrub type of western Utah, the totally different salt desert areas of eastern Utah, and the southern desert type of Washington county; and any of the desert types may be shrubland, grassland, or a mixture of the two with soils varying from clays to sands.

Following is a brief description of each of the major vegetal zones found in Southern Utah:

Southern Desert

This type occurs on only a very small acreage in Washington county, near St. George. Temperatures will exceed 110 degrees, but are seldom below 20 degrees. Soils are not strongly alkaline, but usually have a hardpan. The vegetation itself is very diverse and similar to the southern desert area of northern Arizona and

southern Nevada. The principal plants found here include Prosopis spp., Larrea tridentata, Bouteloua spp., numerous shrubby species of Compositae, and a large number of annuals.

Immediately above the southern desert and below the salt desert and sagebrush zones lies a broad transition zone that is dominated by Coleogyne ramosissima. This transition zone reaches its highest development in southern Nevada.

Although the southern desert type does occur in Utah, it is of such a limited area that it will not be considered further in this problem analysis. It is hoped that the basic research from Arizona and Nevada will be adaptable to Utah with relatively minor changes.

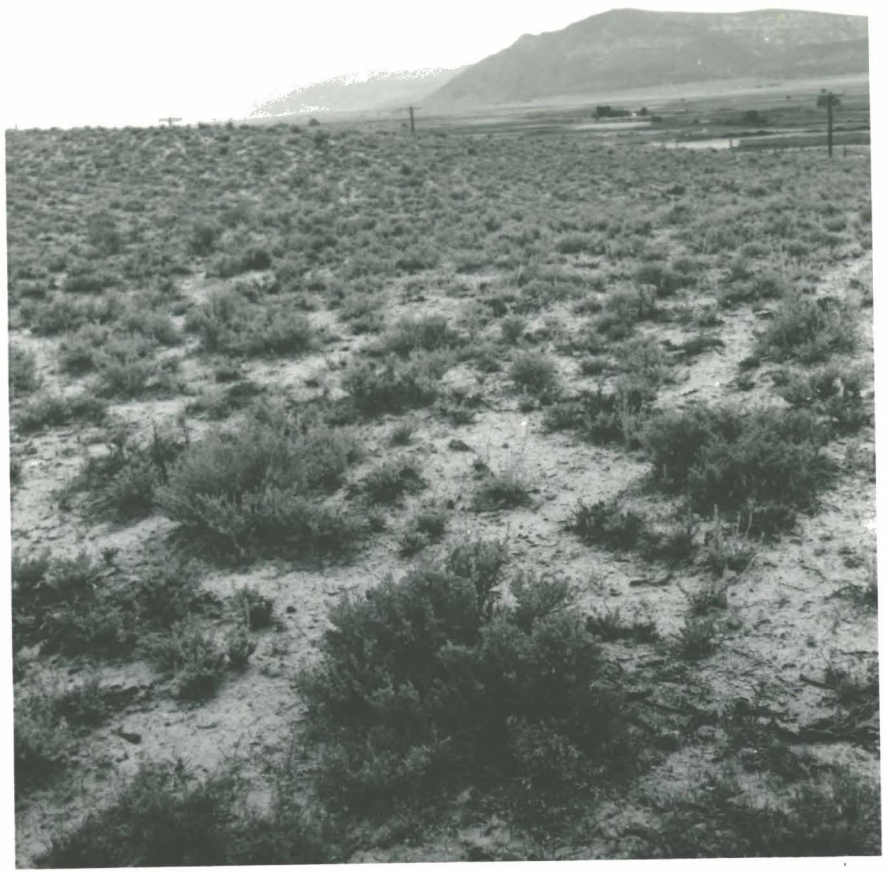
Salt Desert Shrub

The salt desert shrub type occupies vast acreages in western and eastern Utah. This type is a rather broad classification and contains many different communities. It is characterized by Atriplex confertifolia, A. corrugata, Eurotia lanata, Artemisia nova, A. spinescens, Kochia americana, Oryzopsis hymenoides, Hilaria jamesii, and Chrysothamnus spp. All of these species may occur pure or in various combinations with each other. Soils are typically sandy or silty in western Utah, but in eastern Utah will vary from almost pure sands to very heavy clays; the clay soils in eastern Utah are frequently derived from Mancos Shale or associated formations and are typically almost sterile. Salt desert shrub soils are slightly to strongly alkaline and/or saline.

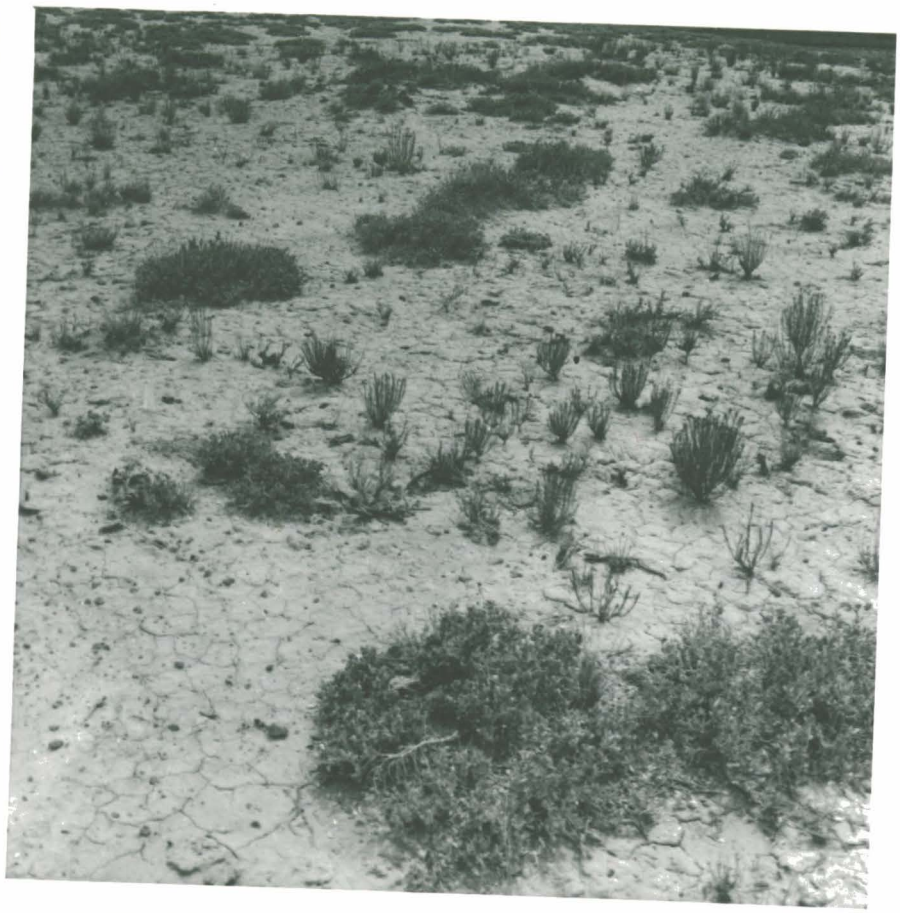
Soils in the vicinity of dry lakes in western Utah are frequently too saline for most plants. Salt desert shrub soils are characterized by a carbonate layer at a rather shallow depth that may or may not form an impervious hardpan. All but a few of these soils are of very low potential even if water were available. Frequent drouths add to the generally unfavorable environment; although much of this area has an average annual precipitation of about six inches, it may drop to a low of 2 1/2 inches in some years.

A limited but important formation in the salt desert shrub type is the greasewood type (Sarcobatus vermiculatus). It frequently contains Chrysothamnus nauseosus, Atriplex spp., or Distichlis stricta as associated species. This type is found on old lake beds or on dry washes. A high water table may or may not be present. Soils are alluvium, usually silt, and rarely show much differentiation into horizons. Salt and alkali are usually abundant.

Reseeding has been tried on a number of sites in the salt desert shrub area, and although initial establishment has been obtained several times, most of the seedings have failed. Where reseeding was successful, the annual precipitation averaged in excess of 8 or 10 inches. However, very little of the salt desert shrub area has an annual rainfall in excess of 8 inches; usually, when rainfall exceeds 8 to 10 inches, the dominant vegetation will be Artemisia tridentata. Much of the salt desert shrub type can be returned to a high level of production by good management alone, but there are large acreages where the vegetation is so badly



Salt desert shrub vegetation growing in Sanpete Valley. The principal plants here are Atriplex confertifolia and Eurotia lanata. Although this site receives more rainfall than most salt desert shrub areas, the general aspect is typical.



Atriplex corrugata and Kochia americana growing on a raw shale soil in eastern Utah. This soil (apparently derived from Mancos Shale) is very sterile, but whether this sterility is caused by lack of fertility, toxic substances in the soil, or both has not been determined. Attempts at reseeding this type of soil have been unsuccessful.

A typical stand of greasewood (Sarcobatus vermiculatus) growing on undifferentiated silt soil. The pH is above 8.5 and salt content is moderately high. This greasewood is of little grazing value.

Drill strip plot of Russian wildrye growing on plot area cleared from greasewood. Russian wildrye is the best adapted grass for this site, but establishment is difficult and seed cost is very high. It provides green feed at any time of the year when soil moisture is sufficient for growth.

depleted that it cannot be returned to a high level of forage production within a reasonable time unless successful methods for reseeding this type can be found.

Sagebrush

The sagebrush type was probably once much more widespread than would be indicated on the summary of range survey types previously shown. Much of the better sagebrush land has been broken up for far lands, and at least a reasonably large amount has been invaded by juniper and is now classed as pinyon-juniper type. It is also one of the most severly depleted range types; the sagebrush type is situated near farming areas and has been heavily used as spring-fall and year long range. At one time, this type was typified by large amounts of bunch-grass in an open stand of sagebrush. With heavy grazing, the grass has been killed out and the sagebrush has taken its place. Because of its depletion and its importance in the year long balance of rangeland, the sagebrush type has received a lion's share of the reseeder's attention. Success in this type has been outstanding, but the problems are far from all being solved.

The sagebrush type is characterized by small deciduous shrubs, primarily Artemisia tridentata. Some other associated shrubs are sometimes found in this type but mostly the type will be pure sagebrush. Annual precipitation is usually less than an average of 15 inches, but this is adequate for good forage growth. Soils are typically moderately deep and of good fertility. In

A good stand of big sagebrush. The understory is scanty, and the area is of little value for grazing. However, sites like this one can produce excellent forage if the sagebrush is eliminated and the area reseeded to adapted grasses.

A comparison of undisturbed sagebrush land and a two year old reseeding. The sagebrush was removed from the reseeded portion by plowing, and the grass seed drilled in the fall. The grass shown here is mostly crested and intermediate wheatgrasses. If this soil were not so stony, it would be good dryfarm land.

the past, a good stand of sagebrush has been used as an indicator of good agricultural land. Most soils contain a carbonate layer, but it is seldom a limiting factor to plant growth. The sagebrush type lies above the salt desert shrub zone and below the pinyon-juniper zone, although in some areas, all three types are intermixed.

Pinyon - Juniper

Some ecologists consider this type to be a transition zone between the sagebrush zone and the yellow pine-mountain brush zone. This type has always been very extensive in this area; it has now expanded into areas where it did not exist prior to the coming of white man. Unless the tree stand is very open, this type has little value as rangeland. The trees have a wide-spreading root system that almost completely controls the soil moisture between the trees; this moisture control eliminates the herbaceous understory. The pinyon-juniper type occurs on alluvial fans, level plateaus of intermediate elevation, and on steep rocky slopes. Where this type occurs on fairly level land, the potential for range reseeding is very high if the trees are first removed. It does not appear that where this type occurs on the steep rocky lands it can be converted to grazing land for domestic livestock at a reasonable cost.

The dominant species in this type are Juniperus osteosperma, Pinus edulis, and P. monophylla. Soils are shallow to deep and of moderate fertility except on the steep rocky sites; they are seldom heavy and are frequently quite sandy. Precipitation averages

A closed stand of pinyon-juniper. Although the crowns do not completely shade the soil, the spreading roots of these two species completely control the soil moisture and prevent any herbaceous understory from becoming established.

An open stand of pinyon-juniper where the roots of the trees do not have complete control of the soil moisture. On this depleted range, a dense understory of cheatgrass is growing between the trees. The original bunchgrass understory on this area has been killed out by overgrazing.

Russian wildrye growing under a former pinyon-juniper stand. The trees on this area were killed with a flame thrower. On many pinyon-juniper areas, successful seedings can be made with a number of species if the trees are first eliminated. An economical method of eliminating the trees is needed.

between 10 and 20 inches annually. This type is usually found at elevations above 5,500 feet but seldom goes above 8,000 feet. Temperatures during the growing season are seldom extreme.

Ponderosa Pine - Mountain Brush

The yellow pine-mountain brush zone typically occurs as a broad belt at elevations between 6,500 feet and 9,000 feet. It is usually above the pinyon-juniper and below the aspen-fir zones. Why mountain brush occurs in some areas while ponderosa pine occupies the similar ecological niche in other areas is a question that ecologists have not yet resolved. The mountain brush generally occurs in the Great Basin Province while the pine is more common in the Colorado Plateau Province. However, this generalization is anything but hard and fast. The best explanation offered to date is that ponderosa pine typically occurs in soils of light to medium texture while the mountain brush is more common on heavier soils; there is some indication that ponderosa pine will not make good growth on heavy soils. In a few areas, the two intergrade, but this condition is not common.

The ponderosa pine type is almost a pure stand of Pinus ponderosa but at higher elevations and on moister sites, Pseudotsuga taxifolia becomes common. Ponderosa pine may occur as a dense stand with little or no herbaceous understory, or it may be a fairly open stand with a fairly good grass understory. Where the ponderosa pine occurs on the high plateaus of the Colorado River Province, the tree stand will contain large grassy openings

or parks. These parks are usually good summer range if not badly depleted. Seeding of these parks has been moderately successful, but the possibilities of achieving a high level of success are very good. Shrub invasion (mostly Chrysothamnus spp.) has been a major problem of the reseeded areas. Soils, although usually light, are commonly moderately deep and of good fertility, but shallow bedrock and rock outcroppings may be common. Annual precipitation averages 17 to 30 inches; in the southern part of the area, the late spring and early summer are usually very dry.

In the mountain brush type, Quercus gambelii is the dominant species, but Acer grandidentatum, Prunus virginiana melanocarpa, Cercocarpus spp., Ceanothus velutinus, Amelanchier spp. and Symphoricarpos spp. are also found. This type occurs mostly on fairly steep lands, but a sizeable acreage occurs on slopes gentle enough to be considered for grazing use. Rainfall averages from 15 inches to over 25 inches. Soils usually are heavy and frequently are rocky. Temperatures are seldom extreme. In most areas, this type has such a heavy brush cover and is so badly overgrazed, that no herbaceous understory is present. A wide variety of species have been successfully planted on the average and better sites in this type. Herbage production is typically very high for rangeland. The herbage is green and at a good grazing stage during the early summer period when the lower ranges have dried up and the high ranges are not yet ready for use. If this type could be seeded on a practical basis, it could be of great usefulness in helping

A typical ponderosa pine stand in Southern Utah. These stands are usually not completely closed and some forage grows in the understory. However, most areas such as this should be managed for timber production, and the reseeding confined to the open parks. This stand has been logged; note the excellent tree reproduction.

A reseeded park in the ponderosa pine type on the Pines Reseeding Project, Dixie National Forest in southern Utah. This area has been successfully reseeded to crested wheatgrass, but there is an excessive amount of little rabbitbrush in the stand. Whether this brush was not eliminated in the beginning or has reinvaded has not been determined.

to achieve a seasonal balance of rangeland. The biggest problem at the present is to find an economical method of eliminating the brush. Most of the species involved appear to be very resistant to herbicides and most of them sprout vigorously after burning.

Aspen - Fir

The aspen-fir type is a transition zone between the ponderosa pine-mountain brush zone and the sub-alpine type. The elevational range of this type is 8,000 to 10,000 feet. The aspen-fir type is quite variable; in some areas it may be almost pure fir while in other areas it will be principally aspen. In most areas the two species will be mixed, although the mixture may consist of an intermingling of small patches of pure fir and pure aspen. In many locations, the aspen appears as a pioneer community, and now, many young fir trees are to be found in the understory. The aspen is all Populus tremuloides while the fir is principally Abies concolor; other species of Abies, Picea, and Pinus may occur in lesser amounts. Soils are variable but are usually quite fertile if not excessively rocky. Annual precipitation is generally above 20 inches.

The fir stands have very little herbaceous undercover and are of almost no value as grazing land. On the other hand, all but the densest stands of aspen have an herbaceous understory, the quality of which is inversely proportional to the density of the aspen stand. Much of the aspen type is valuable as grazing land. Although most of the aspen areas have been badly depleted by over-

General view of part of the Major's Flat reseeding study area located in the mountain brush type (Elev. 7,000 feet). The hills in the immediate background are typical of the mountain brush zone.

Grasses established under oak canopy by broadcasting the seed just prior to leaf-fall. This picture was taken before the oak leaves had mad much growth. Shading under this dense a canopy is very heavy by mid-summer. Grasses are principally smooth brome and orchard grass. This is a good site and could be converted to valuable rangeland by reseeding if an economical method of eradicating the oak could be found.

Smooth brome growing on a good soil cleared of mountain brush. Many of the mountain brush soils are very fertile and produce high yields when the brush is eliminated.

Reseeded grasses growing under a medium stand of aspen. Smooth brome, Kentucky bluegrass, and tall oatgrass are the principal species in this picture. The grass seed was broadcast in fall of 1941 just prior to leaf-fall. Picture was taken in 1954.

A comparison of reseeded and unseeded areas in an opening in the lower aspen-fir zone. The seeded area supports a dense stand of Kentucky bluegrass; the unseeded area is covered with a thin stand of worthless annual weeds.

grazing, reseeding has been reasonably successful and herbage yields have been satisfactory if not high.

Sub-Alpine

The sub-alpine type is commonly referred to as the spruce-fir zone but this name is somewhat misleading. Although there are some locations where the spruce and fir form an almost continuous forest, the trees most commonly occur as scattered small stands with a grass-herbaceous broadleaf type in between. These large areas of herbaceous cover have made this type one of the most valuable for summer grazing; however, it is also one of the most seriously depleted. Many of the valuable range plants have been killed out and herbage yield is far below what it formerly was. A large amount of topsoil has been lost through accelerated erosion. Past experience with reseeding in the sub-alpine type indicates that the forage production potential is still very high; a number of adapted species have been found. Much of the annual streamflow in this region originates in the sub-alpine areas. All too frequently summer floods also originate in the sub-alpine type. The importance of this type as watershed land is probably greater than its value as grazing land, but as grazing land it is extremely important for summer range. Because of its value for both watershed and range, the need for continuing reseeding research in the sub-alpine type is very great.

The timbered areas are primarily Picea engelmanni and Abies lasiocarpa, with a very scanty herbaceous understory. The flora

General view of sub-alpine vegetation. Most areas have more timber than shown here, but the herbaceous vegetation between the clumps of trees is typical. Note the light colored raw soil areas; these are all severe sites or snowdrift ? areas.

of the untimbered areas was originally very rich in species of grasses and herbaceous broadleaves. Many of the original species were highly palatable, but most of these have been all but eliminated and have been replaced by unpalatable species. The original soil was shallow to deep, but erosion has reduced the depth over most of the area. Some of the shallower soils have been eroded down to the underlying rock and talus. The potential on these severely eroded slopes appears to be quite low. Rainfall is generally in excess of 30 inches annually with about 80 percent coming as snow. Soil moisture is usually adequate for growth until very late in the growing season. Temperatures are low during the growing season and killing frosts are not uncommon even during July and August.

Arctic-Alpine

The arctic-alpine type occurs on only a very limited acreage in southern Utah on the highest crests and peaks. The vegetation consists of low growing forbs and sedges. As grazing land, it has almost no value.

Other types

There are several other types occuring in this area that cannot be truly classed as range, but because of their importance in the over-all balance of seasonal forage, they deserve brief mention. The principal types of interest here are the wet soil areas in the valley bottoms, irrigated land, and dry farm land. How much these three types are developed and improved will determine

to some extent the demands that can be expected to be put on the range land. In some cases, the development of additional high quality forage could relieve some of the pressure on the ranges. For example, high producing irrigated pastures and the development of high producing hay fields and pastures on the currently underdeveloped wet soil areas could greatly reduce the critical shortage of summer grazing land. Because most of the research on these lands is being carried on by other workers, it will not receive further consideration here, but progress of research on these lands must be kept under consideration in order that the range reseeding and fertilization research program may be kept current.

RESEARCH NEEDS

There are three general fields in which research needs to be carried on --- methods and techniques for establishing the stand, species adaptability and strain trials, and methods of increasing forage yield. Some work has been done in each of these three general fields at Ephraim; however, most of the effort has been concentrated in the field of species adaptability. Because of the concentration of work in species adaptability, at least some species have been found that are adapted to most of the sites found in this area with the exception of the salt desert shrub type. For some sites, quite a large number of species and strains have been found that are well adapted. This is not to say

An excellent stand of reed canary grass growing on muck soil west of Ephraim. Reed canary grass plantings such as this yield up to seven tons of hay to the acre per year, whereas the depleted native grasses yield less than a ton. The development of these areas could do much to relieve the grazing pressure on the nearby range land.

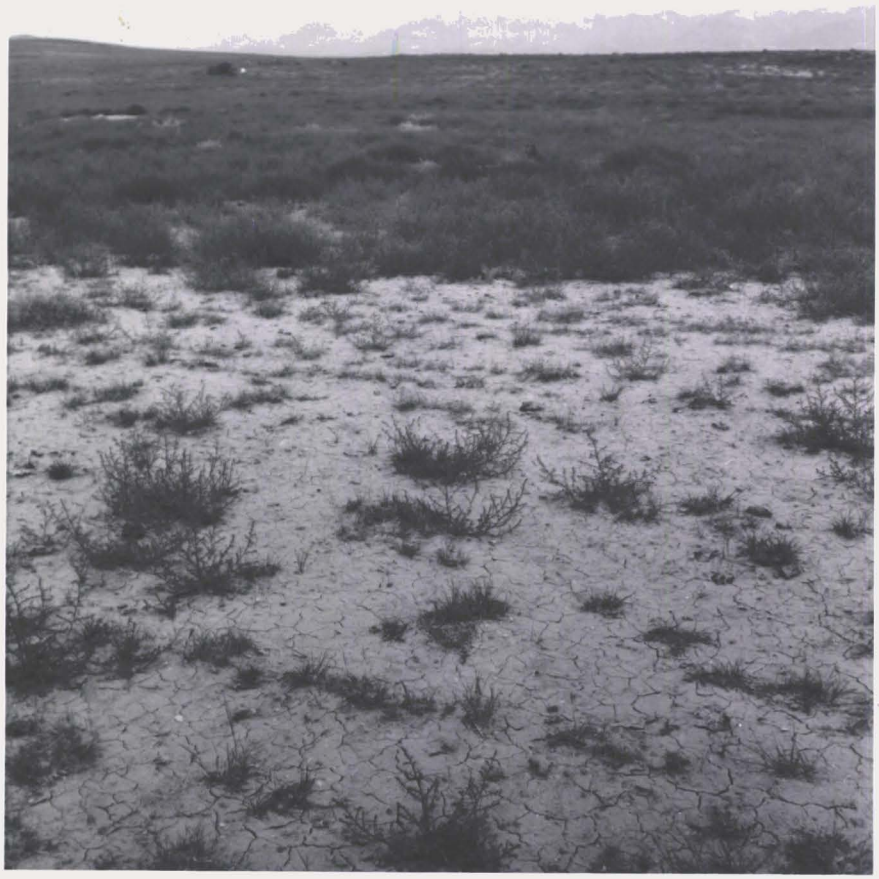
that we have determined the best species and strains for these sites, but field scale plantings are not stopped for lack of an adapted species.

However, we are now faced with the problem of knowing what to plant but not knowing the best way of planting it. Many large scale reseeding projects have failed even though adapted species were used. In some cases, the failure could be attributed to just plain poor farming. On the other hand, there have been many of these failures where no reason for the lack of success could be found. It has been felt that if the methods of planting had been correct, most of these failures could have been prevented. In order to try to eliminate these failures, the future research of highest priority will be to determine the best possible methods and techniques for seeding rang lands.

Following are brief descriptions of proposed fields of investigation to be studied in future years. This should not be considered a complete list, but it is believed to cover the most pressing problems as seen today.

Methods of Planting.

Generally, spring planting has given the best results in range reseeding. However, the period during the spring when planting can be done is very limited, and some of the mountain areas are still inaccessable because of snow drifts. For these reasons, most range reseeding is done in the fall after temperatures are low enough to prevent germination. It has been observed that many



The foreground shows a successful experimental seeding; the background shows an unsuccessful large scale seeding. The unsuccessful seeding is now over-run with Russianthistle. The experimental seeding of crested wheatgrass, even though very heavily grazed, is able to control the weedy plants. The reason for the failure on the large scale seeding is not known. When a seeding fails, the area is frequently invaded by low value species which in some cases can make further reseeding very difficult. This area is in the salt desert shrub type in Sanpete County; rainfall is above 10 inches annually.

of the planted seeds are destroyed by fungi during the winter and early spring. With the present high costs of seed used in range reseeding, if seed treatment could reduce this loss by even a few percent, the cost of treating the seed could more than be repaid by reducing the per acre seeding rate. There may actually be some areas where seed treatment might even spell the difference between success and failure. If seed treatment should prove successful, there will be the continuing job of testing the new fungicides as they become available.

The placement of a narrow band of fertilizer under the seed at the time of planting has been shown to be very beneficial in getting the forage plants established under some eastern conditions. This technique has not been tried under our arid western conditions. There is a good possibility that the use of band fertilizer placement in range reseeding may give the seedlings enough of a boost that the seedlings will become well enough established to withstand the severe growing conditions frequently encountered. The eastern studies also indicated that the band fertilizer placement aided the grass and legume seedlings in overcoming weed competition during the first year. On some sites in this area, competition from weeds has appeared to be detrimental to the establishment of the seeded grasses, and a treatment that would help the seeded grasses to compete with the weeds might make the difference between success and failure.

It has been commonly observed at Ephraim that planting seed in

the bottom of a furrow has usually given better results than conventional drillings. The use of a deep furrow drill has usually been recommended for all large scale seedings. However, no studies have yet been made to determine how great the benefits of deep furrow planting might be, how deep the furrows should be, the best furrow shape, depth of seed placement in the furrow bottom for best germination and growth, or the effects of the furrows on the microclimate in which the seedlings develop. Until these questions can be answered, recommendations concerning the use of deep furrows must be based on guesswork. It may be also necessary to develop new drills suitable for deep furrow drilling on range land; the present deep furrow farm drills are far from satisfactory.

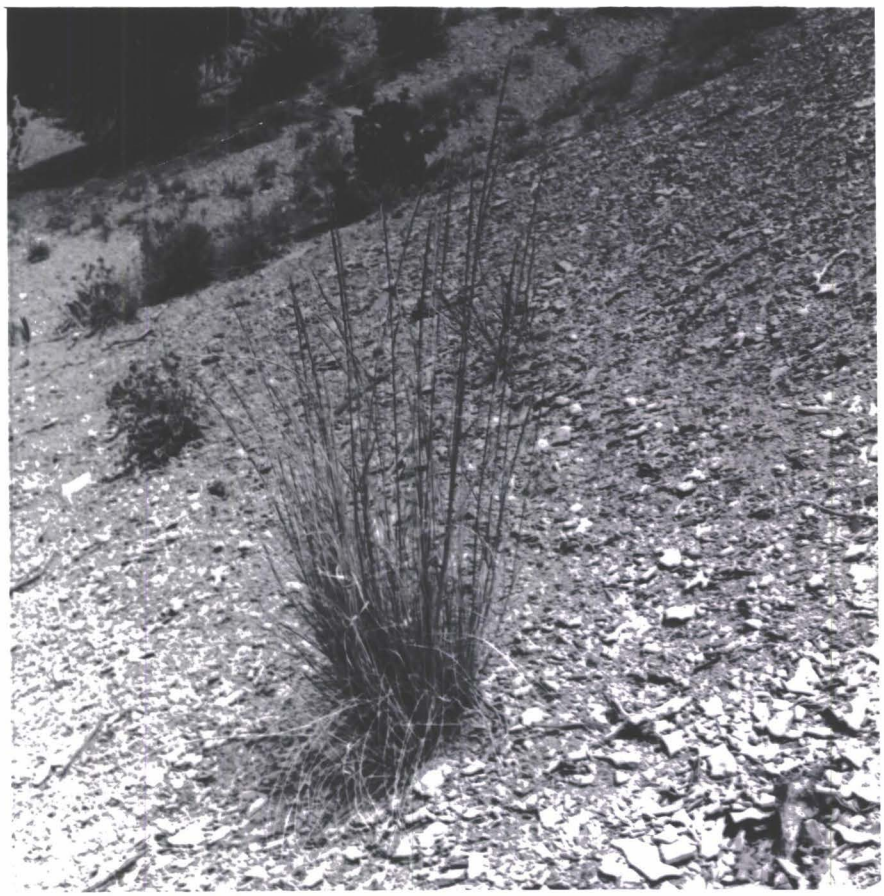
It has been pretty well understood that a firm seed bed is desirable for good reseeding success. However, firming a seedbed requires an additional operation after the competition has been removed by plowing. The present cost of range reseeding is very high and any additional operations will raise the cost still higher. It would be desirable to determine just how firm the seedbed must be for satisfactory germination and establishment. Many of the past failures in reseeding can probably be charged off to too loose a seedbed, but we have had no criteria by which to judge this. When standards of seedbed firmness have been established, it will be necessary to develop practical methods of firming the seedbed and measuring firmness under field conditions.

Practical methods of determining to soil crusting potential

of a soil have been developed by the Salinity Laboratory, but as yet, no practical method of eliminating the soil crusting problem in range reseeding has been found. There are several sites in this area where soil crusting appears to be a limiting factor in getting stands established. No leads on this problem have yet been found.

On a number of severe sites, it appears that the microenvironment may be responsible for the failure of seedlings to become established. This appears to be especially true on bare south-facing slopes. There is a strong possibility of an unbalance between soil and air temperatures in the early spring; this would result in the soil temperature being high enough to start germination during a period when air temperatures were too low to permit the emerging seedlings from living and growing. The intense radiation received by these slopes appears to cause the soil to dry out very early. Until the effects of these microclimatic effects can be determined, it is not likely that successful methods for reseeding severe sites can be developed. The effects of the interrelations between soil temperature, air temperature, and soil moisture are mentioned here with particular reference to south-facing slopes, but similar environmental factors probably are influential in the lack of success in seeding other arid sites.

The use of cover crops in range reseeding has been generally unsuccessful. However, in most cases, an annual cover crop has been planted at the same time as the perennials were seeded. The



A plant of intermediate wheatgrass growing on a severe south slope. On such severe sites, it has frequently been found that plants will grow if they can become established. To find methods for establishing grasses on these severe sites is of high priority.

use of a preliminary planting to improve the site or to modify the microenvironment has not received much attention. Some sites are so badly depleted from accelerated erosion or are naturally so severe to begin with, that the modification of these sites with annuals or special perennials should be considered. In some cases, it will be necessary to control erosion before reseeding can be considered; this technique has been used successfully on the Great Plains where a small grain is planted one year and the perennial grasses are drilled into the stubble the following year. In some areas, it may be possible to establish low value perennials and then find methods whereby at a later date the higher value grazing plants can be established in the existing stand of low value plants. This might be analagous to introducing clovers into established pastures in the process of pasture renovation. The whole process of using low value or annual plants to improve the site could be likened to the process of natural plant succession where one community so modifies the environment as to make it unsuitable for that community but ideal for the establishment of a community higher on the ladder of plant succession.

One serious problem in large scale reseeding jobs is finding equipment that is suitable for the job to be done. Standard farm machinery can be used in a few cases although it usually requires additional strengthening. There are no facilities available at Ephraim for the design or construction of new reseeding equipment even if time were available for this work. However, the testing

of new commercial equipment that looks promising should not be neglected. Also, cooperation with the Range Reseeding Equipment Committee must be considered as an important job in range reseeding research. Until such time as more efficient and durable reseeding equipment can be found, range reseeding will remain too expensive for many situations.

Species Adaptability and Strain Trials

Species adaptability trials need to be extended into several areas where previous work is not conclusive. The areas needing immediate attention are the salt desert shrub, pinyon-juniper and ponderosa pine types in the Colorado Plateau Province, and severe sites in general. Work in the salt desert shrub type will be largely dependent upon future imports of exotic species not previously tried or in finding methods of seeding suitable for the native species. Many of the native species can provide excellent forage, but for one reason or another, it is very difficult to get satisfactory stands with them.

Where an adequate number of strains are available for testing, strain trials should be carried out with species known to be adapted to a given site. Past experience indicates that there are some noticeable differences in strains, both in persistance and in forage production. Similarly, significant differences from various seed sources of the native species have been observed.

One serious problem in range reseeding is to find suitable legumes. Some very promising legumes have been found, but all of

these have had some serious drawbacks. At the present, alfalfa looks as promising as any legume tested, and the great amount of work currently being done in the development of grazing types of alfalfa will necessitate continual testing of the new strains. It is hoped that a suitable legume can be found in the near future so that detailed testing of grass-legume mixtures can be started.

How much moisture is needed to germinate seed of range grasses remains a question that needs to be determined to aid in the interpretation of studies involving methods of seeding. Because there is the possibility that there will be differences in the inherent abilities of different species to germinate at low levels of available moisture, this general problem is considered as being one of species adaptability. Modern methods and techniques for testing germination under a moisture stress have been developed to the point where a study of this type can be undertaken. This study should be started in the immediate future so that the results will be available to aid in the interpretation of species adaptability and methods of planting studies currently under way.

Many of the species found to be adapted to the various sites in this area have not been adequately tested to determine their relative palatability or their resistance to grazing use. Although some of the species have been tested in other areas, it is questionable that these data should be extended into southern Utah until adequate local tests have been made. There will probably be little difference in the relative palatability of a species growing in

Ladak alfalfa that has been heavily grazed for 10 years. These plants make little growth but are able to persist under this degree of utilization. To date, alfalfa looks as promising as any legume for range reseeding; the new strains being developed will probably be much better and will need to be tested.

southern Utah as compared to the same species growing in another region, but there could easily be a noticeable difference in its ability to persist under grazing pressure even though it does very well when not grazed.

Increasing Forage Yields

Past research in range reseeding has been primarily concerned with finding adapted species, and to some extent, with finding methods of planting. In some locations, we are now to a point where sizeable acreages have already been seeded; this is particularly true in the sagebrush type. In these locations, some attention should now be given to methods of increasing the forage yield.

The first and most logical method to try is that of applying mineral or organic fertilizer. Past results in this field have not been encouraging, but past work has little more than scratched the surface. Future work will need to be concerned with kinds of fertilizer, rates of application, season of application, and trace elements.

Many of the range soils are of rather low permeability. Mechanical structures that retain rain where it falls until it has a chance to enter the soil have received only limited attention. Contour furrows and terraces have been used successfully in controlling runoff on flood source areas, but they have not been adequately evaluated in terms of their ability to increase forage yields. The possibility of using these water retaining devices as an aid to stand establishment as well as for increasing forage yields should

not be overlooked. If water retention structures should prove beneficial, a search should also be made to find machinery and techniques that will build these structures at a low cost.

There is a good chance that the use of grass mixtures and grass-legume mixtures will increase the total yield of forage on some areas. Mixtures may also be useful in extending the grazing season as a result of different growth habits of the species used in the mixture, and there is a very good chance that grass-legume mixtures can provide forage of a higher nutritional level than a pure grass or a grass mixture. Before the mixtures can be completely evaluated, it will be necessary that they be given rather thorough tests under actual grazing conditions. Past experience with mixtures indicates that to find a mixture that will provide the maximum forage yield and not have its relative composition changed as a result of selective grazing by the livestock is no mean task. This is particularly true on arid sites where the grazing methods used so successfully on irrigated pastures are not feasible.

The optimum plant spacing of the individual plants in range reseeding has not yet been determined. Most range sites do not have a moisture supply adequate to maintain a continuous plant cover, particularly when bunch grasses are used. It would be desireable to find the spacing that will give the highest forage yields and at the same time give adequate protection to the soil from erosion. A study of this subject should also consider the effects of plant spacing on forage quality because spacing can

Contour terraces constructed on watershed above Mt. Pleasant, Utah. This picture was taken shortly after a high intensity summer storm (note water held in terraces). These terraces prevent soil erosion until the reseeded grasses can control the site. What effect these terraces have on forage production has not been determined.

affect the growth form of the individual plants which in turn could affect the nutrient level of the plants. When the opitimum spacing has been determined, it will then be necessary to find a method of planting that will provide this optimum plant spacing.

Other Studies

There are several other studies that are badly needed but which fall outside the scope of this problem analysis; they are mentioned here only because of their extreme importance to the over-all range reseeding research program. Before species are recommended for general use, the best methods of grazing management should be determined so that the maximum benefits of reseeding can be realized. For some sites, particularly the mountain brush type, effective and economical methods of eliminating the undesireable plant competition must be found before large scale seedings can be undertaken; at present, the selective herbicides are showing the most promise but a great amount of work is yet to be done. Many reseeded stands have been invaded or reinvaded by shrubby species, particularly sagebrush and rabbit brush. Studies should be started to determine the reasons for this brush invasion and to find economical methods for eliminating the brush form the established stand.

A severe case of brush reinvasion on a reseeded range. This area is on the Pines Reseeding Project of the Dixie National Forest. In this case, rabbitbrush has invaded a relatively good stand of crested wheatgrass. Brush reinvasion on reseeded ranges is a serious problem in this area.

APPENDIX

Progress During 1954

Plot rating. (FCc9-2)

A major job planned for 1955 is the preparation of the cooperative manuscript "Adaptability of species for seeding climatic zones in Utah." Much of the field and office time in 1954 has been spent gathering and summarizing data for this publication. Most of the data gathered have been of a supplementary nature or for the purpose of bringing the records up to date on infrequently rated studies. The 1954 data, along with the data collected during the past 20 years by the Forest Service, will serve as the basis of the publication. Although the Forest Service is taking primary responsibility for this publication, the contribution by the Agricultural Research Service will be considerable. One major job of A.R.S. is to provide such additional field data as is required.

Arasan Treatments. (FCc9-3)

One formal study was started during 1954; this study is to determine the effectiveness of Arasan in preventing seed destruction by soil fungi during the winter when the seed is planted in the fall. It is not the purpose of this study to evaluate the relative effectiveness of various fungicides, but rather, to determine the possible advantages to be gained by using a suitable fungicide on fall-planted grass seed.

The Arasan treated seeds are being tried at three separate locations --- Summit Enclosure, Major's Flat, and Sorenson's Field. Summit Enclosure is located on top of the mountains in the sub-alpine

type at the head of Ephraim Canyon; the elevation is 10,500 feet, with an annual precipitation of 35 inches; the seed will be in the ground about seven months before any germination takes place. Major's Flat is located in the lower mountain brush type in Ephraim Canyon; the elevation is 7,500 feet with a precipitation of 15 inches; the seed will be in the ground about six months before germination. Sorenson's Field is located just south of Ephraim in the lower sagebrush zone; the elevation is 5,600 feet with an annual precipitation of 10 inches; the seed will be in the ground about five months before germination.

The following species were planted at the three locations: Summit Enclosure: smooth brome, meadow foxtail, tall oatgrass, slender wheatgrass, timothy, and orchard grass. Major's Flat: Russian wildrye, intermediate wheatgrass, tall wheatgrass, smooth brome, crested wheatgrass, giant wildrye, and beardless bluebunch wheatgrass. Sorenson's Field: crested wheatgrass (standard), crested wheatgrass (fairway), giant wildrye, Russian wildrye, beardless bluebunch wheatgrass, and western wheatgrass.

The plantings at each location consisted of five replications of each species. One hundred Arasan treated seeds of each species were counted out and planted in a row six feet long; one hundred untreated seeds were planted in the adjacent row.

It is planned to make seedling counts as soon as germination starts in the spring. Additional counts will be made at frequent intervals until it is felt that the seedlings have become established.

Careful observations will also be made for any evidence of damping-off; if any damping-off is observed, a check will be made to determine if Arasan has any effect on reducing its incidence.

Fertilizer studies. (FCc9-3)

Three preliminary band seeding trials were put out in the fall; these studies are located at Summit Enclosure, Major's Flat, and the greasewood area (elevation 5,500 feet with an annual precipitation of 10 inches). These studies are entirely exploratory in nature. They are for the sole purpose of making general observations on band seeding when used in conjunction with fall seeding. If any posative results are obtained, a detailed study involving kinds and rates of fertilizer will be started.

On these band seeding trials a mixture of equal volumes of ammonium nitrate and treble superphosphate was applied at what appeared to be a reasonable rate. The fertilizer was placed in the ground with a Planet Jr. with the planting shoe set at maximum depth. On the alternate rows, the planting shoe was pushed through the soil but no fertilizer was used; this made soil treatments identical. The Planet Jr. was also used to plant a mixture of adapted species above the fertilizer bands and in the unfertilized rows.

An observational study of the effects of broadcasting nitrogen and phosphorus on established vegetation was started in cooperation with the Utah Experiment Station. In all, five sets of plots were put out, one on top of the mountain on an old stand of smooth brome,

one on native vegetation just below the top of the mountain, two at Major's Flat on established reseeded mixtures, and one at Sorenson's Field on an old stand of crested wheatgrass. Fertilizer was applied at the rate of 50 pounds of nitrogen per acre and 84 pounds of phosphoric acid per acre. The nitrogen and phosphorus were put on alone and in combination; two replications were used. If results from any of these trials appear promising, further studies of types, rates of application, and season of application of the fertilizer will be made.

Problem Analysis. (Fcc9-2 and FCc9-3)

Because I had not had the chance to see the results of many of the seedings made in the past in this area, some time has been spent in looking at these seedings and in trying to size up the problems involved. A number of contacts have been made with public land administrators, Soil Conservation Service technicians, and farmers for the purpose of finding out what their problems were relative to range reseeding. The summarization of this work is the problem analysis that constitutes this year's annual report.